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DECISION MAKING WITH ANALYTICAL HIERARCHY PROCESS FOR SELECTION OF FURNACE FOR FOUNDRY INDUSTRY

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ABSTRACT

The different manufacturing sectors in the era are striving hard to introduce innovative long-term strategies into their operations. The aim of the study is to integrate those advanced techniques with sustainable operations; to promote advanced sustainable melting process so these manufacturing sectors can thrive even in uncertain markets. To establish this connection, this study analyzes the drivers of the advanced sustainable melting process through a proposed framework validated using a case study in India. Common drivers are collected from the literature, calibrated with opinions from experts, and analyzed through an Analytical Hierarchy Process (AHP), which is a multi-criteria decision making (MCDM) approach. This study reveals that quality is the most important alternative that pressures foundry sectors to adopt advanced sustainable melting process. Manufacturers can quickly note the top-ranked driver and adapt it to implement advanced viable foundry soundly.

KEYWORDS: Advanced Sustainable Melting Process, Parameters, AHP & MCDM

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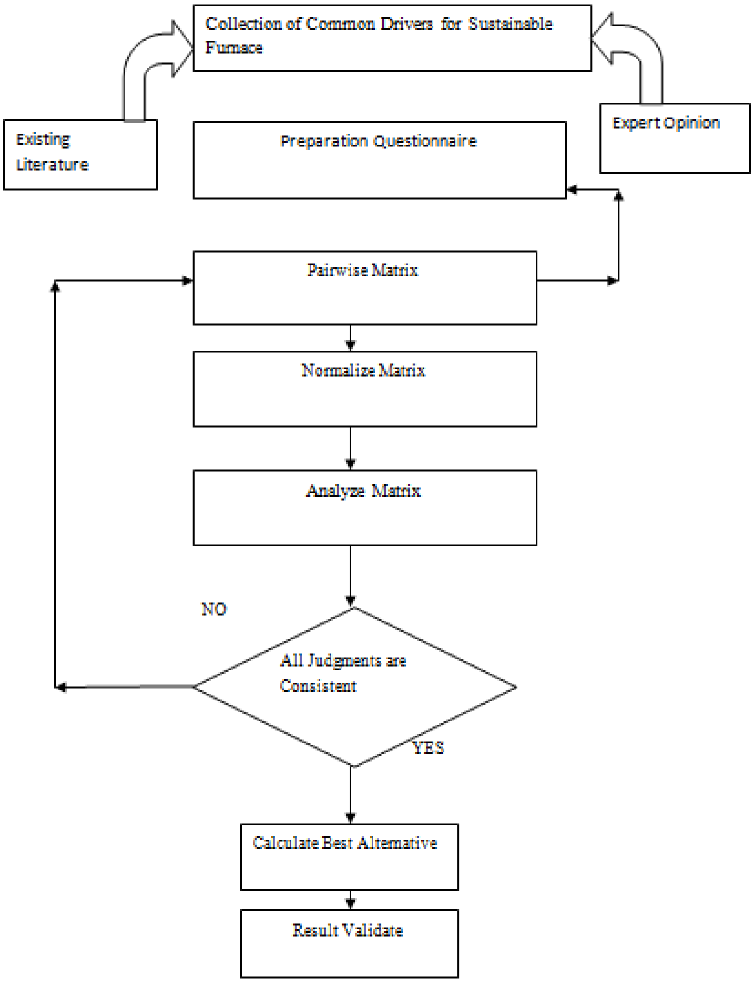
Original Article

1. INTRODUCTION

A choice made from alternatives is known as a decision. Decision making is the process of adequately decreasing the uncertainty and the doubt about the other options to allow a limited choice to be made among them. There are various approaches such as the analytic hierarchy process (AHP), fuzzy multiple-attribute decision-making model, linear and 0-1 integer programming models, genetic algorithms, etc. have been considered for different decision-making problems. Wang et al. [1] suggest a fuzzy multiple-attribute decision-making model assist the decision maker to deal with the machine selection problem for the flexible manufacturing systems (FMS). The linear 0-1 integer programming model of machine tool assignment and the operation allocation in the FMS is suggested by Atmani and Lashkari [2]. The model which is formulated as a 0-1 integer programming to determine machine visiting sequences for all part types for an integrated machine tool selection and sequencing is proposed by Moon et al. [3]. Subramaniam et al. [4] suggest a method for selection of machines. Haddock and Hartshorn [5] proposed a decision support system (DSS) to assist in selecting a machine which is required to process specific dimensions of a part. A multi-criteria weighted average approach is suggested by Arslan et al. [6] for selecting a suitable machine from the database of machines available in the market. Triantaphyllou and Mann [7] tested some of the practical and computational issues involved when the AHP method is employed in the engineering applications. Lin and Yang [8] studied the evaluation of machines by using the AHP method. The study is related with the selection of the most suitable machine from a wide range of the machines available for the manufacture of a particular type of the parts. Tabucanon et al. [9] developed a decision support framework which is designed to aid

decision makers in selecting the appropriate machines for the FMS. Oeltjenbruns et al. [10] investigated the compatibility of AHP to strategic planning in the manufacturing. The objective is to develop/explore different planning alternatives ranging from extending the life of existing machinery to total replacement with a new manufacturing system and to evaluate these alternatives through economic and technological criteria. Yurdakul [11] presents a model which links machine alternatives to manufacturing strategy for furnace tool selection. In this study, the evaluation of investment in machine tools can model and quantify strategic considerations by using the AHP method. On the other hand, Cheng and Li [12] claim that although AHP is a useful tool for management decision making, it can be defective if misused. Cost, sensitivity, energy efficiency, precision, and reliability analyses are included for making an accurate selection. The overall decision methodology is implemented employing Microsoft Visual Basic. The remainder of the paper is organized as follows: Section 2 discusses multi-criteria decision making as well as cost, sensitivity, reliability, and precision analyses. The principle idea behind MCDM is to construct a decision tree employing a selection of criteria concerned to a particular decision and the weighting/scoring of criteria and alternatives for each of the various criterion. According to Triantaphyllou [13], MCDM is divided into multi-objective decision making (MODM) and multi attribute decision making (MADM). MCDM methods may be further classified as deterministic, stochastic or fuzzy according to the data type they utilize. Another classification is based on the number of decision makers involved: single or group decision makers Triantaphyllou [13]. Each method uses numerical techniques to help decision makers choose among a discrete set of alternatives. Selecting the best MCDM method is the first step in a decision making problem. There are six concepts related to the MCDM: Alternatives, attributes, criteria, sub-criteria, weights of importance, and decision matrix. Despite the criticism multi-dimensional methods have received, techniques such as weighted sum model (WSM), weighted product model (WPM), AHP, revised AHP, ELECTRE, and TOPSIS have been widely used. We will briefly summarize AHP and revised AHPand refer the reader to Triantaphyllou [13] for the details of other methods. Analytic Hierarchy Process AHP is a necessary multi-criteria decision-making approach introduced by Saaty [14]. In this approach, the decision maker carries out simple pair-wise comparison judgments, which are then used to develop overall priorities for ranking the alternatives. In making decisions, deciding what factors to include in the hierarchic structure is the most crucial task. When constructing hierarchies, one must consist of enough relevant detail to represent the problem. The elements of comparison should be homogeneous. A hierarchy may be divided into sub-hierarchies sharing only a common topmost element. Problem Description Manufacturers realize that technical improvements can help protect the firm from unexpected economic crises, and help them to meet the customer expectations when the decreasing resources threaten the company/Firm. No studies currently exist which combine technological advancements with the sustainable concerns, so this study seeks to integrate automation with sustainability in the manufacturing sectors. The most common motivating factors are called as drivers, so once drivers are identified, it will be the easy task for the manufacturers to employ those drivers for improving their rate of the advanced sustainable manufacturing. The model framework, as presented in Figure 1, depicts the drivers of advanced sustainable manufacturing. Due to the reliability of proposed frame-work is under question unless it is validated, this proposed frame-work was applied to a case industry situated in the Indian geography. Generally, as discussed earlier, developing nations are still far behind in adopting efficient long-term strategies.

Framework of Study



The proposed framework starts with the collection of common parameters of an advanced sustainable Melting process from the support of existing literature and experts' opinion. Once the common parameters are collected, the questionnaire is prepared along with the rating scale. From the obtained replies of the case industry's decision makers, a pair-wise comparison has made among the common drivers; this step is an initial process required for AHP. The pairwise comparison matrix is synthesized, and drivers' priority is constructed. Further, a consistency check is performed to validate the AHP process. If the consistency check is successful, then the drivers' priority is revealed along with their corresponding ranks.

2. METHODOLOGY

Advanced sustainable foundry gives an organization with the many advantages but choosing an appropriate strategy is still a critical task because, upon occasion, a company may face conflicting factors. To handle multi-criteria problems, this study features a multi-criteria decision-making methodology. There are a number of MCDM techniques available, but Analytical Hierarchy Process (AHP) is among the most powerful. Originally proposed by Saaty in 1980, AHP has been applied in a variety of applications; it measures intangibles with the assistance of experts' judgments through pair-wise comparisons. The step-by-step methodology of AHP application is detailed below Step 1: Select the list of attributes (drivers) related to an advanced sustainable manufacturing system combined from the assistance of existing

literature review and the field experts' notions. Step 2: From assistance of the decision makers, create a pairwise comparison on the given criteria. This comparison will be based on Likert 5- point scale further modified to the Saaty scale for the numerical ease. Step 3: Evaluate the global weights by formal arithmetic operations of the AHP including the normalization. Step 4: Further, check the reliability of the results through the Consistency Index (C. I.) and the Consistency Ratio (C. R.) Step 5: When the C. I. < 0.1, then the verdict is satisfactory. Otherwise, pair wise comparisons can be repeated to elucidate the error. The progression must be cyclic process until the consistency condition is made satisfactory. Step 6: Then, based on the final weights, the drivers of advanced sustainable manufacturing are prioritized and further circulated to the case industry's decision makers to focus on the most highly-weighted driver.

The Saaty scale is the scale proposed for explaining the relative significance of factors one over the other. For example, according to the Saaty scale, if criteria A and criteria B is measured to have a pairwise comparison, and if A is seven times greater important than B, then it is represented as 8; if B is seven times greater important than A, then it is represented as 1/7. As mentioned above, each and every criterion is analyzed by comparing one with them, and from this process, the weights of criteria and sub-criteria are identified.

3. PROPOSED MODEL

For validating the proposed model, it was applied in case industry. This company is one of leading manufacturers in the India. This case industry introduces many new innovative technical and technological strategies within their operations to sustain their business, and they have been successful in business for several years. Hence, they needed to improve their organizational culture to achieve more intangible benefits rather than focusing only on fiscal performance. By coincidence, our research team had just sent a proposal to this case industry explaining the new age of manufacturing and its benefits. Presently, this industry follows the lean manufacturing standards with an emphasis on the waste reduction; they had not yet considered automation technologies or the sustainable strategies. Our study arrived at a point which might be highly useful for this firm to retain their position in the fluctuating business market. With the industry's approval, our research team sought to validate proposed model, which was categorized into three phases: (i) collection of the drivers; (ii) application of the AHP; and (iii) The verification of results.

3.1. Phase I

Collection of Common Drivers of the Advanced Sustainable Manufacturing In the first phase of the proposed model there is a collection of the common drivers of advanced sustainable manufacturing through the assistance of existing literature and the opinions of the field experts. The established standard search procedure was followed using the essential terms of the research, such as "advanced manufacturing," "sustainable manufacturing", "drivers", and so on.

3.2. Phase II

Application of AHP Once the common drivers were collected, the next step was the analysis through analytical hierarchy process (AHP). Because the conceptual and preliminary steps of AHP were explained in previous sections, we list here the four necessary steps. _ Step 1: Based on the obtained replies of case industry decision makers and the support of the Saaty scale, a pairwise comparison among the collected common drivers of advanced sustainable manufacturing was made, Step 2: The pair-wise comparison matrix was normalized with standard arithmetic operations to form a normalized matrix, which has elements ranging from 0 to 1. Step 3: From the normalized matrix, Eigenvalues were obtained and posed for a consistency check for ensuring that the consistency ratio should be less than 0.1. _ Step 4: Finally, the priority of the

factors is ranked based on the Eigenvalues obtained by each driver.

3.3. Phase III

Result Validation although, the decision makers from the industry provided the in-depth problem concepts, we have to check the reliability of the obtained results. We compared the results obtained with existing literature and with the case decision makers.

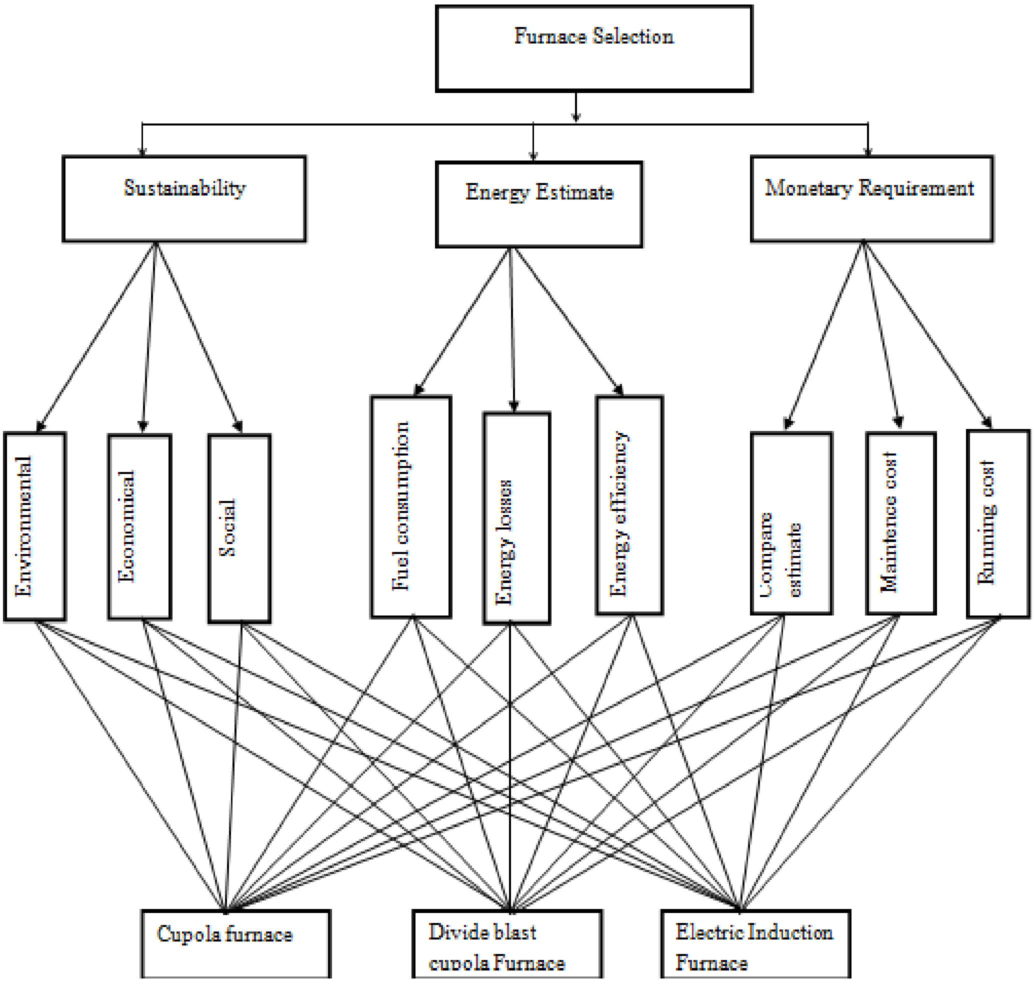


Figure 3.1: AHP Criteria, Subcriteria and Alternatives

Table 3.1: Pair wise Matrix of Sustainability

	Environment	Economical	Social
ENVIRONMENT	1	0.11	0.33
ECONOMICAL	9	1	0.33
SOCIAL	3	3	1
SUM	13	4.11	1.66

Table3.2: Pair wise Matrix of Sustainability

	Fuel Consumption	Energy Lossess	Energy Efficiency
FUEL CONSUMPTION	1	0.14	0.11
ENERGY LOSSESS	7	1	0.33
ENERGY EFFICIENCY	9	3	1
SUM	17	4.11	1.44

Table 3.3: Pairwise Matrix of sustainability

	Compare Estimate	Maintenance Cost	Production Cost
COMPARE ESTIMATE	1	0.14	0.11
MAINTENANCE COST	7	1	0.11
PRODUCTION COST	9	9	1
SUM	17	10.14	1.22

Table 3.4: Normalize Matrix of Sustainability

Sustainability	Environment	Economical	Social	SUM	Average(Weight)	Sum/Weight
Environment	0.0769	0.00908	0.076388	0.162368	0.05412267	3
Economical	0.6923	0.743187	0.22916	1.6646647	0.55488233	3.00036
Social	0.23076	0.2477	0.6944	1.17286	0.39095333	3.000025

Lambda=3.000128 CI= lambda -1 /(n-1) CI=0.000064 CR=CI/RI=0.0002133

Table 3.5: Normalize Matrix of Energy Estimate

Energy Estimate	Fuel Consumption	Energy Loss	Energy Efficiency	Sum	Average(Weight)	Sum/Weight
Fuel Consumption	0.0580	0.03381	0.0766388	0.1681	0.0560	3
Energy Loss	0.4117	0.24154	0.22916	0.8823	0.2941	3.000034
Energy Efficiency	0.5294	0.72463	0.6944	1.9484	0.6494	3.000003

Lambda=3.000012, CI= lambda -1 /(n-1), CI=0.000006 CR=CI/RI =0.000002

Table 3.6: Normalize Matrix of Monetary Requirement

Monetary Requirement	Compare Estimate	Maintenance Cost	Production Cost	Sum	Average(Weight)	Sum/Weight
Compare Estimate	0.58	0.0138	0.0901	0.1619	0.05396	3.0037
Maintenance Cost	0.4117	0.0986	0.0901	0.6000	0.20013	3.0018
Production Cost	0.5294	0.8875	0.8196	2.2365	0.7455	3

Lambda=3.001833 CI= lambda -1 /(n-1) CI=0.0009165 CR=CI/RI = 0.0003055

Table 3.7: Alternative Matrix

Alternative Matrix					
		Sustainability %	Production %	Monetary Requirement %	Energy Estimate %
Alternative 1	**Cupola Furnace**	5.41	8.11	5.39	5.60
Alternative 2	**Divided Blast Cupola**	53.48	24.03	20.01	29.41
Alternative 3	**Induction Furnace**	39.09	67.84	74.55	64.94

Criteria Matrix
0.25
0.25
0.25
0.25

Table 3.8: Weighted Alternative Matrix

		Weighted Matrix
Alternative 1	**Cupola Furnace**	6.13 %
Alternative 1	**Divided Blast Cupola**	31.73 %
Alternative 1	**Induction Furnace**	61.60 %

4. PHASE III: RESULT VALIDATION

Although the decision makers from the case industry provided the in-depth problem concepts, we wanted to check the reliability of the results. We compared the results obtained with the existing literature and with the case decision makers. A detailed description of this phase is documented in upcoming sections.

5. CONCLUSIONS

Selecting the most suitable furnace from the increasing number of the available furnace is a challenging task. Sustainability, production, monetary requirement, and energy estimate capabilities all depend on the furnace properties. In this study, machine tool selection problem is addressed and an AHP based methodology is proposed. In order to apply this methodology, the machine properties and main and sub-decision criteria are investigated. This study's objective was to explore the necessity of adding sustainable strategies into advanced manufacturing systems, and we determined that an effective first step was to identify strategy drivers and practices. We analyzed the drivers, collected both from literature resources and from experts' opinions, and created a model framework which we validated with an Indian case industry. Study utilized the analytical hierarchy process (AHP) because it is a skillful tool to identify weights of factors under multi-criteria. Our study revealed that "Induction furnace is the major driver of advanced sustainable manufacturing systems. Our study has provided both scientific and technical contributions but includes some limitations. Studies done in other regions of India might reach different results.

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